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ADDING DISTRIBUTIONS TO ASCAM

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13. ABSTRACT *(Maximum 200 words)*

Although large simulation and optimization models exist for mobility planning, these require significant setup time, and were not designed for "quick and dirty" estimates of closure times. The Airlift Sealift Cycle Analysis Model (ASCAM) was designed using Excel for "quick and dirty" transportation mobility analysis. This report describes work performed by Dr. Sam L. Savage in coordination with the Directorate of Plans and Policy, US Transportation Command (USTRANSCOM). The work provided improvements to the ASCAM model as follows: User Interface - separate data from formulas to allow scalability. Stochastic Modeling Capability - uncertain numbers may be modeled by distributions whereupon Monte Carlo simulations can be run. The resulting model ASCAM3.1, allows numbers not known with certainty (like MOG - Maximum On Ground capacity), to be replaced with stochastic representations (distributions), whereupon a Monte Carlo simulation may be run. the result is that: the potential for errors in the expected closure are reduced and it is possible to provide the user with a range of closure times and associated probabilities using ASCAM.

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Abstract

This report describes work performed by Dr. Sam L. Savage in coordination with the Directorate of Plans and Policy, US Transportation Command (USTRANSCOM).

The work provided improvements to the Airlift Sealift Cycle Analysis Model (ASCAM) model as follows.

1. User Interface
   Separate data from formulas to allow scalability, provide map.
2. Stochastic Modeling Capability
   Uncertain numbers may be modeled by distributions whereupon Monte Carlo simulations can be run.

1. Executive Summary

Introduction

Although large simulation and optimization models exist for mobility planning, these require significant setup time, and were not designed for "quick and dirty" estimates of closure times. Accordingly, members of USTRANSCOM developed a spreadsheet model in Excel 5 known as the Airlift Sealift Cycle Analysis Model (ASCAM). ASCAM was designed to quickly estimate closure for movements of various units from a single specified Air POE and a single Sea POE.

The original ASCAM implementation showed that a small model for forming rough estimates would indeed be useful, however there were areas of deficiency:

1. The model was not readily ***scalable***, that is, if one wished to add additional aircraft types or units to be moved, considerable reprogramming of the model would be required.
2. The model was deterministic, that is, it used point estimates for numbers that were not known with certainty. For example, one might not know in advance what the bottleneck (MOG) would be at the off load field. Even if one uses an accurate estimated of the mean value of MOG, a deterministic model gives an incorrect estimates of closure (see Appendix B).

Purpose of This Contract

The purpose of this contract was to create an improved model that addressed these two deficiencies. That is, refine the user interface to allow for more direct addition of new aircraft types and units, and add a stochastic information capability. These improvements were to be tested, and the improved model delivered to USTRANSCOM.

2. Results of Contract

1. Stochastic Modeling

The resulting model ASCAM3.1, allows numbers not known with certainty, to be replaced with stochastic representations (distributions), whereupon a Monte Carlo simulation may be run. The result is that:

a. The potential for errors in the expected closure are reduced
 and
b. It is possible to provide the user with a range of closure times and associated probabilities. The histogram below shows the wide range of possible closures brought about by uncertainty in MOG (see Appendix B).

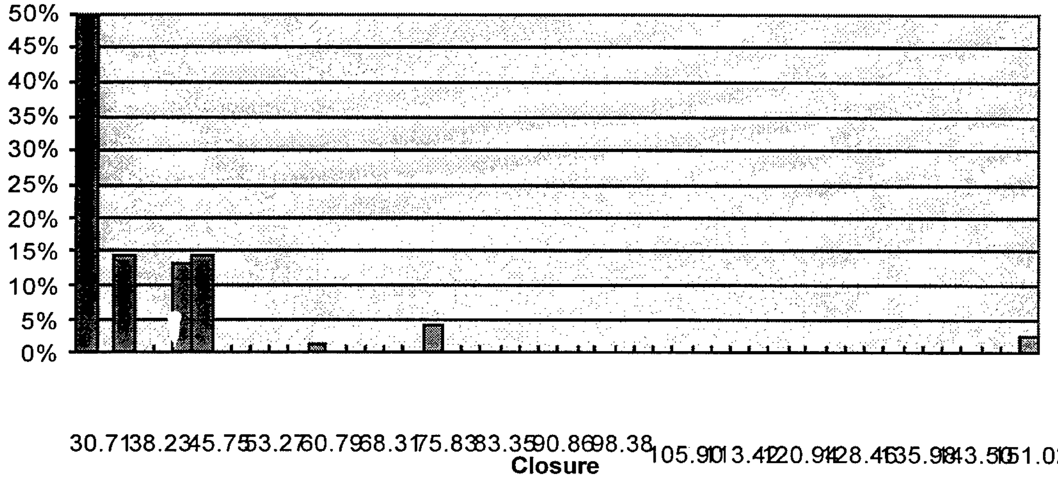


Figure 1 - Distribution of Closure

2. User Interface

The user interface of ASCAM3.1 is improved in several fundamental ways (See Appendix A).

a. Model hardening by separating formulas from data.
b. Scalability improved. It is now possible to add new plane types and unit types.
c. Added Map to user interface as shown below.
d. Model thoroughly documented.
e. Model kept live so that distributions and Monte Carlo simulation can be used.
f. Given the time allotted it was agreed that it was more important to achieve the major changes listed above for a single mode. Thus only airlift is supported in ASCAM3.1 A "production" version would also include sea lift (see next steps below).

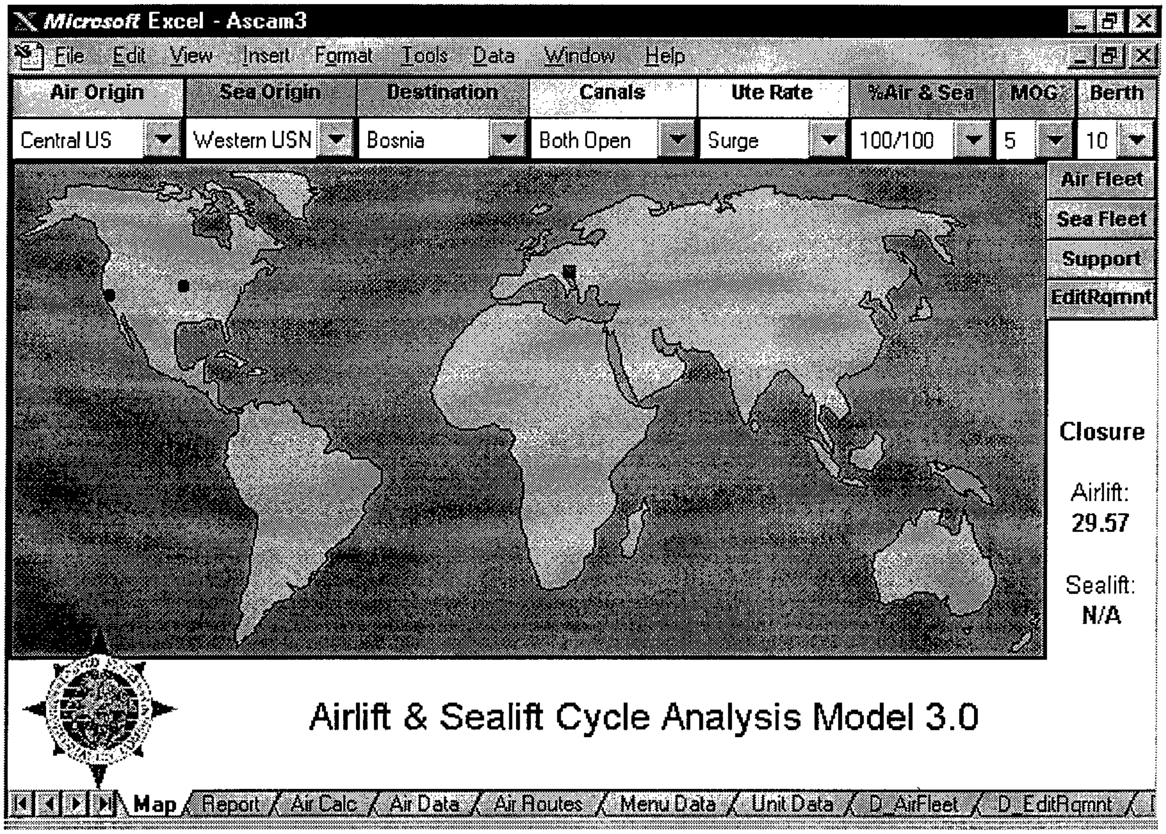


Figure 2 - New Interface With Map

3. Knowledge Acquisition

On July 2nd, Dr. Savage visited TRANSCOM at Scott AFB to introduce the basic concepts behind spreadsheet simulation, and initiate investigation of the primary uncertainties in the ASCAM model. On August 1st and 2nd Dr. Savage attended the 5th AIRFORCE MOBILITY M&S USERS' GROUP meeting at the NPGS in Monterey to learn more about the overall issues of mobility modeling. His primary finding from these meetings were:

a. There are several places in mobility modeling where the use of point estimates for uncertain numbers may create significant errors (see Appendix B).

b. The use of point estimates is not limited to the original ASCAM model, but appear in the larger mobility models such as MIDAS and MASS.

c. It appears that some estimated mobility closures for the Gulf War significantly underestimated actual closure. This may have been due at least in part to the fact that the models were deterministic instead of stochastic.

d. It appears that the current large simulation models such as MIDAS and MASS do not need to be re-written in order to handle stochastic variables. Instead it may be possible to run them in a Monte Carlo mode without developing new software.

4. Presentations

a. Dr. Savage made presentations of final results to USTRANSCOM on September 4th. Those present included ADM Chaplin (J5), Mr. Frank Weber (J5-V), COL George Danish (J5-A), Tom Denesia (J5-AA), Dan Noonan (J5-AA), Karyle Pardise (J5-AI), Dave McDonough (J5-AI), Jay Marcotte (J5-SC Contractor). ADM Chaplin liked the concept of the "quick and dirty" approach. He indicated that adding sealift was the highest priority in any future development. Mr. Weber suggested that the large scale mobility models would also benefit from the Monte Carlo and sensitivity analysis performed with ASCAM3.1.

b. Dr. Savage demonstrated ASCAM3.1 to Norman Weinberg of OSD and Neal Glassman of AFOSR at the Pentagon on September 16. Norman suggested that an additional source of uncertainty was the actual composition of a Heavy Brigade or other such unit. Neal expressed surprise that stochastic modeling was not being done regularly in the large mobility models.

c. Later on September 16th Dr. Savage and Norman Weinberg met with Jim Johnson of OSD to discuss the general idea of stochastic modeling in mobility models. Jim said that some Monte Carlo experimentation had been done with the large models, and that it looked promising. He also indicated that queuing considerations in the large models deserved additional attention.

3. Next Steps

A Production Version of ASCAM

Interest has been expressed in developing a future version of ASCAM3.1 which supports both airlift and sealift, and preserves the ability to model uncertainty. The specifications of such a system were discussed at the September 4th 1996 meeting. They have been summarized below according to urgency.

A . Must Have

1. Model Sealift
2. Adjustment capability for % Sea vs. Air
3. Model with 2 or 3 average ship types
4. Sealift cargo in Short tons (sum out, over, bulk)
5. Operator entered number for:

Origin to POE
POD to foxhole

6. Outputs (Sea vs. Air):
   Cost
   Closure (on load, transit & off load times)
7. Use current approximation for loading cargo on planes and ships.
8. Adding new unit requirements and aircraft will be "push button" automated.
9. Model will be fully documented.

B. Should Have

10. Group interval ships in parallel
11. Queuing Effects
12. Better Understand of Airlift/Sealift Loading
13. Air/Sea Radio Buttons (i.e. for each movement unit, ability to select if that unit is transported by air or sea.
14. Calculated Origin to POE
15. Calculated POD to foxhole
16. Road or Rail (push button with look up tables)
17. Ship types with attributes (10 categories)
18. Area Volume AV by Unit (ref: sealift (ft2, TEUs, FEUs,MTONS)
19. Model will be fully documented.

C. Potential Enhancements

20. Surface Model
21. Dynamic Priority
22. Access database
23. Others to follow

4. Interim Reports

Appendices (Interim Reports) follow.

Appendix A: Hardened Spreadsheet Model

7/19/96

Appendix A Outline

Hardened Spreadsheet Model

Knowledge Acquisition

Key areas in which to use distributions

I. Hardened Spreadsheet Model

The user interface of ASCAM 2, an Excel 5 model was improved by students in a projects course at Stanford University. A description of the Improved model and its documentation appear in appendix B. The primary improvements of this model are:

1. Hardening by separating formulas from data.
2. Increased scalability. It is now possible to add new plane types and unit types. This required indirect addressing, and index statements
3. Added Map to user interface
4. Model thoroughly documented
5. Model kept live so that distributions and Monte Carlo simulation can be used.

Knowledge Acquisition

On July 2nd I visited Tom Denesia and others at Scott AFB. The purpose of the visit was

1. To deliver and describe the hardened model to Denesia and others involved in airlift/sealift.
2. To determine initial key areas in which distributions must be modeled in transportation models.

Key areas in which to use distributions

I have currently identified several ways in which uncertainty in input parameters may influence the accuracy of transportation models. This is not an exhaustive list, but should serve to help analysts detect problems in their models. These are ranked according severity of their effect, ranging from benign to malignant.

Linear model, large number of independent uncertain inputs

Example

Uncertain Input: Tons loaded on a particular aircraft type varies from load to load. Tons to be moved are known.

Output: Number of missions needed to complete airlift.

Comments: It is reasonable to estimate the number of missions M by

M = Average(Tons/Mission)*Tons to be moved especially when M is large.

Linear model, small number of uncertain inputs

Example

Uncertain Input: Tons that can be loaded on a particular aircraft type. Either High or low, does not vary from load to load. Tons to be moved are known.

Output: Number of missions needed to complete airlift.

Comments: Technically speaking

M = Average(Tons/Mission)*Tons to be moved

But this is NOT reasonable. It will either take more than this if Tons/Mission takes on high value, or less if low value. If discrepancy is large, M should be expressed as a distribution, that is; M will take on one of two values with estimated probabilities.

Non Linear model Small number of uncertainties

Example

Uncertain Input: Number of planes per hour (N) that can pass through off-load point, same for all planes. Suppose N is either 1 or 3 with equal probability and suppose it is known that M missions must be flown.

Output: Hours (H) required to get M missions through off-load point.

Comments: Average value of H IS NOT = M/(Average N = 2)
Suppose N could either be 0 or 4, then average N is still 2, but average of H = (.5*M/4 + .5*M/0) = infinity!

Queuing Models

Example

Uncertain Input: Length of time to unload plane at off-load point varies from plane to plane, average is OLT.

Output: Queue length

Comments: Average queue length if arrival interval is average of OLT hours is 0 if actual OLT does not vary. Queue length may grow indefinitely if actual OLT varies from plane to plane. This is a famous result from queuing theory which must not be ignored.

Appendix B: Stochastic Spreadsheet Model

Contract F30602-96-C-0215

Adding Distributions to ASCAM

Sam L. Savage

8/5/96

Appendix B Outline

Some Areas in which Uncertainty is not Adequately Modeled

Simple Spreadsheet Example Model

Mobility Users' Group Meeting at NPGS

Stochastic Spreadsheet Model

Next Steps

I. Some Areas in which Uncertainty is not Adequately Modeled

MOG

A key concept in mobility models is the bottleneck at an airfield which limits the number of planes through per hour. This is related to MOG (maximum on ground). Suppose for example that 10 plane loads are needed for a mission, and the bottleneck at the off load airfield is 2 planes per hour. Then the time to close the mission would be 10 planes / 2 planes/hr = 5 hours. Of course, MOG is not known with certainty in advance. For example, during the Gulf War, there was a large airport in Saudi Arabia with high predicted MOG. However, when forces arrived, there turned out to be only one fuel hydrant. Thus MOG was much smaller than predicted.

So how should a mobility model deal with uncertain MOG? The time honored tradition is to plug in the average or best guess. For example, suppose the estimate of 2 for the bottleneck above was based on the following analysis: There is a 50/50 chance that the field will be muddy with a MOG of 1, otherwise MOG will be 3. This gives an average of 2. Then our estimate in advance of the expected closure is 10/2 = 5. However, this is wrong. 50% of the time closure will be 10/1=10 hours, and 50% of the time it will be 10/3= 3.3333. So the expected closure is 13.33/2 = 6.66. Suppose that the estimate of 2 above, is the average of 4 and 0? Then closure given expected MOG (F(E(X))) is still 5, but expected closure (E(F(X))) is infinite!

Queuing Model

When I was at Scott AFB last month, I came upon another potential area in which the modeling of variability may be improved. In a Transcom simulations of airlift/sealift, times, such as those required to unload freighters are modeled as constants. That is, they don't vary from ship to ship. According to Queuing Theory, this would indicate that the models may systematically underestimate the number of ships waiting for service. This does not necessarily indicate a shortcoming in the model itself, but suggests that it could be used in new ways to achieve greater accuracy. I believe that it may be straightforward to introduce this sort of uncertainty modeling into the current simulation models without additional software development.

II. Simple Example Spreadsheet Model

The file SIMPLE1.XLS contains a set of examples of Simple Models of Airlift Cycles to be run using the SIM.XLA Monte Carlo Simulation routines. These models show the effects of adding increasing levels of uncertainty to a mobility model. The various sheets are described below.

1. DETERMINISTIC - Averages are plugged into model for all uncertainties. Closure is 5 days.
2. UNCERTAIN PLANES - The number of planes is now uncertain. Closure is either 2 or 8 days, thus average is still 5.
3. UNCERTAIN MOG - Average MOG remains the same, but average closure goes to 6.66.
4. BOTH UNCERTAIN - Both MOG and Planes uncertain. Spread goes up but average still 6.66
5. 2 UNCERTAIN MOGs - There is now an Enroute and Off load MOG, both uncertain. Overall MOG is the minimum. Average closure is over 8.

These models clearly show the systematic errors which may result from modeling uncertain inputs with expected values. This example could be expanded to incorporate the effects of statistical dependence among the inputs, which might make the errors even more severe.

Mobility Users' Group Meeting at NPGS

On August 1st and 2nd I attended the 5th AIR·FORCE MOBILITY M&S USERS' GROUP meeting the NPGS in Monterey.

I learned that the MIDAS and MASS mobility simulations do not currently model uncertainty, and do not address points discussed in I. and II. above.

Apparently the actual mobility performance in the Gulf War was roughly half that predicted by the simulations. This may be due in part to the lack of uncertainty modeling. It should therefore be a high priority to introduce uncertainty into current mobility models. I believe that it may be possible to accomplish this through repeated runs of the current simulation systems, and that no additional personnel or software will be needed.

IV. Stochastic Spreadsheet Model

Simulation of Uncertain MOG - ASCAM31U.XLS

Operation

A version of ASCAM31.XLS has been developed to model uncertain MOG. It is called ASCAM31U.XLS, and is attached. It may be used as follows:

1. Distributions for Onload, Offload and Enroute MOG are entered on the Air Data sheet in cells H8, I8, and J8 as shown.

2. Then a simulation is run with SIM.XLA using Closure (cell J15 on Map sheet) as the output cell.

Enter Distributions for MOG's in cells below. Then specify Closure on Map as output cell.		
Default MOG		
Onload	Offload	Enroute
10	5	3

An Example

The model was set up to move 1 Heavy Brigade, 1 Light Brigade, and 1 Fighter squadron from the Central US to Bosnia. Air Fleet specifications and MOG were as shown to the right, and above.

WBPAX	N/A	15
C_5	1	17
C_17	2	25
C_141	3	56

Deterministic Model

With this deterministic input, the Closure (cell J15 on Map sheet) is 29.57 days.

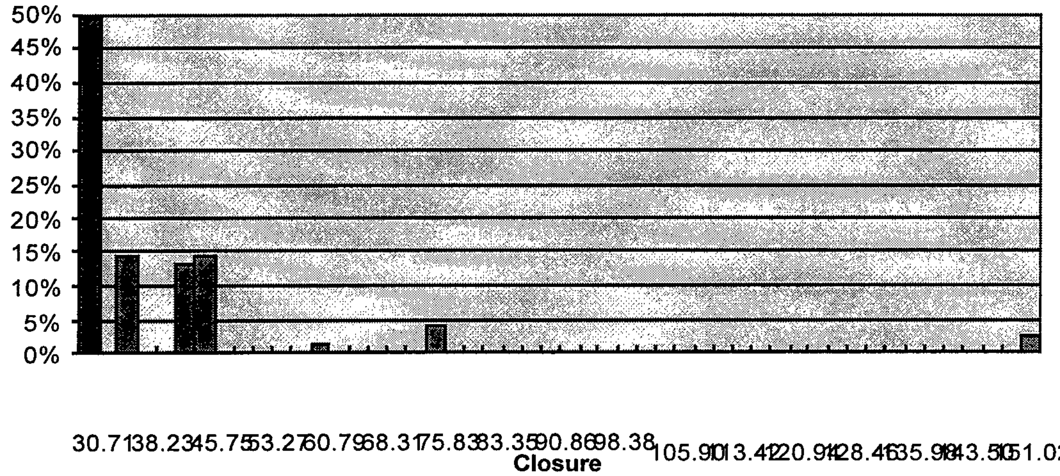
Stochastic Model

In general determining the distribution of possible MOG values will be an important aspect of using stochastic models. However, even using the wrong distribution may be more accurate than using an accurate estimate of the mean as a point estimate. To demonstrate an example of the qualitative effects of introducing uncertainty, independent distributions were chosen for the three MOGs which yielded positive integer values and had the correct mean. A convenient way to accomplish this was to use a value of 1+gen_Poisson(N-1), where N is the mean of the

desired MOG. NOTE: This was done for qualitative purposes, and does not necessarily reflect a realistic distribution in practice.

The result with 500 trials was an expected closure of about 40 days instead of about 30 days predicted by the deterministic model. The distribution of outcomes is revealing. The histogram below shows that there is a 50% chance that closure is very close to 30 days, but reasonable chances of it being as long as 45 days, and some chance of it being over 150 days!

Simulation of Uncertain MOG - ASCAM31U.XLS



Days to Closure as a Functions of C-17's and C-141's - ASCAM31T.XLS

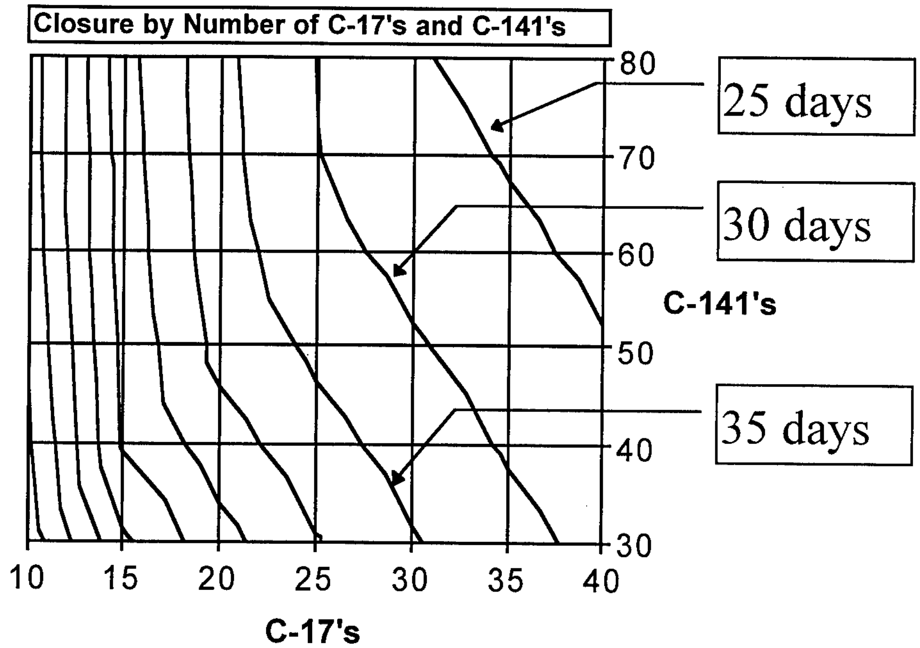
An Example

A two way data table was set up in ASCAM31.XLS to demonstrate how to determine days to closure as a function of number of planes available. This has been saved as ASCAM31T.XLS. The Onload, Offload and Enroute MOG have been set deterministically at 10,5 and 3.

The model was again set up to move 1 Heavy Brigade, 1 Light Brigade, and 1 Fighter squadron from the Central US to Bosnia. Air Fleet specifications allowed only C-141's and C-17's as shown for a more interesting trade-off.

WBPAX	N/A	15
C_17	1	40
C_141	2	70

The Data Table is set up on the Air Data sheet, driven by Closure in cell O21. The row and column input cells are L21 and L22 respectively. The results have been graphed on the Air Data sheet just above the table. The contours represent increases in closure of 5 days.



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